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Design of Embedded Automated Fingerprint Identification System Based on DSP

Sun Hong

Security & Protection Department,

Zhejiang Police Vocational Academy, Hangzhou, Zhejiang, China, 310018

sunhong@zjjy.com.cn

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Abstract: The automated fingerprint identification algorithm has high time and space complexity in the embedded system. How to reduce the complexity is one of the hot research topics. The process of fingerprint identification and choice of algorithm platform are analyzed in the paper. Design of embedded fingerprint identification hardware system based on DSP, including the selection of microprocessor and fingerprint sensor and the communication between them, is introduced in detail. In additional, main software composition and flow are explained. At last, serial peripheral interface communication is simulated.

1. Introduction

With the rapid development of computer and information technology, biometric identification technology has been concerned widely. Biometric identification is the process by which a person can be identified by his characteristics. Using biometric identification is a more secure method of identifying a person because the characteristic in question is a part of that person. This means that it cannot be easily shared, traded, or stolen by another. There are mainly two categories of biometrics identification: physiological characteristics and behavioral characteristics. Physiological biometrics has to do with the physical traits of a person, and behavioral biometrics has to do with the things that can change with the environment. For example, a fingerprint, a physiological characteristic, does not usually change except for accident or illness, but a signature, a behavioral characteristic, can change as a person ages. Examples of physiological biometrics include fingerprinting, retinal scans and handprint scans. Behavioral biometrics includes verifying signatures and voice recognition. Each biometric identification can be described by some parameters, such as universality, uniqueness, permanence, acquisition, performance, acceptance, anti-deceptive. According to the scoring statistics above parameters, fingerprint identification has the highest score [1]. According to the statistics of International Biometric Group (IBG) which is the biometric and identity management industries' leading independent integration and consulting firm, the market share of fingerprint identification is approximately 66% with increasing market income year by year [2]. So fingerprint identification is the most in demand biometric identification in the world.

In recent years, a lot of progress of automatic fingerprint identification technology has been made at home and abroad and there are many fingerprint products. That many people think that automatic fingerprint identification technology has been completely solved. But The results by the test of Fingerprint Verification Competition(FVC) show that automatic fingerprint identification

technology still has many problems to solve. High accuracy computational algorithms requires a relatively long time and consumes more storage space, this resulted in the difficult to accept for users in the practical applications. Therefore, embedded fingerprint identification system based on high-performance CPU is one of research directions. Hardware and software of the fingerprint identification system based on DSP are studied in the paper.

2. The process of fingerprint identification

Generally, automated fingerprint identification has three steps, including image acquisition, feature extraction and feature matching. A fingerprint is made of a series of ridges and furrows on the surface of the finger. Image acquisition is that ridges and furrows information of the fingers obtained through the device are converted into digital image. Feature extraction is that the fingerprint features are extracted from the digital image. Feature matching is if the fingerprint features match with one of fingerprint database. Thus, matching two fingerprint images generally match the extracted features between the fingerprint images.

Automated fingerprint identification systems mainly have two types. One is fingerprint verification and the other is fingerprint identification. For verification, user need input username and fingerprint, and then the fingerprint template stored in the database is searched through the username. Two fingerprints are matched by one-to-one way, so the system is called one-to-one matching system. For identification, user only need input fingerprint, then it are compared many times with the fingerprint templates stored in the database, so the system is called one-to-many matching system [3](see Figure 1).

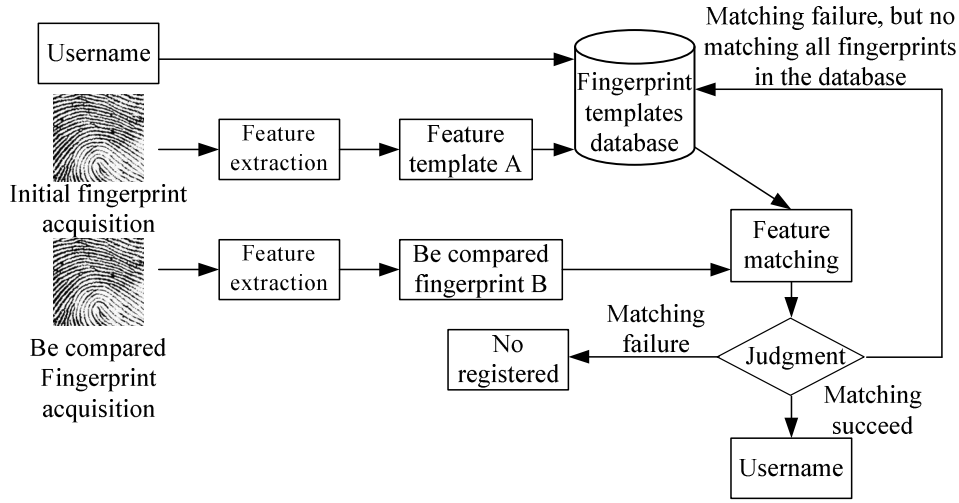

Fig. 1 Identification process of one-to-many matching system

2. Platform choice for fingerprint identification algorithm

Fingerprint identification algorithm is the core technology of the products. Currently, fingerprint identification algorithm based on the PC is relatively mature, but application of fingerprint identification algorithm based on variety embedded systems is relatively large space for development. Because the computing and memory resources in embedded systems are limited, it is difficult to implement the fingerprint identification algorithm in the embedded system.

Now, embedded fingerprint identification algorithm is based on DSP or ARM generally. If system platform is DSP, algorithm performance is relatively stronger and identification speed is faster, but algorithm is more difficult to development and cost is higher. If system platform is ARM,

development difficulty is lower, but identification speed and performance are worse only for common applications. By comparison, embedded fingerprint identification system based on DSP is selected.

3. Hardware design of embedded fingerprint identification system

3.1 System architecture

Take fingerprint access control system as the example, it includes the microprocessor, fingerprint sensor, LCD display module, small keypad, real time clock calendar chip, electromagnetic lock and power and so on. Microprocessor controls the whole system. Fingerprint identification module implements fingerprint feature acquisition, matching, storage, and delete functions; Liquid crystal display module displays open records, real-time clock, operating tips and other information. LCD and small keypad compose man-machine interface. Figure 2 is the system architecture of fingerprint access control system.

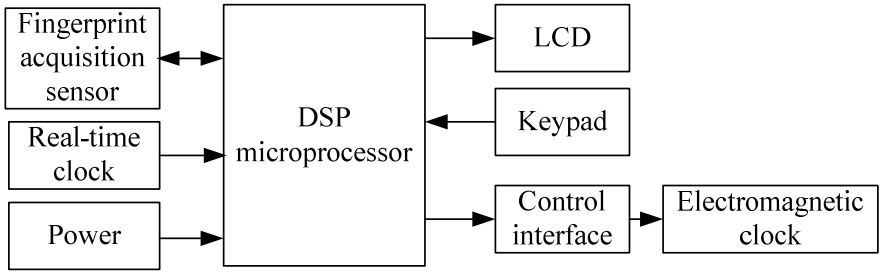

Fig. 2 The architecture of hardware system

3.2 Choice of the microprocessor

Considering product price performance ratio on the basis of extensive market research, single-chip microcomputer SPCE061A is choice. The SPCE061A, a 16-bit architecture product, carries the newest 16-bit microprocessor μ'nSP™, developed by SUNPLUS Technology. This high processing speed assures the μ'nSP™ is capable of handling complex digital signal processes easily and rapidly. It includes following features [4]:

- CPU clock: 0.32MHz - 49.152MHz
- 32K-word flash memory
- 2K-word working SRAM
- Two 10-bit DAC outputs
- 32 general I/Os (bit programmable)
- 14 INT sources with two priority levels
- Eight channels 10-bit AD converter
- Serial interface I/O (SIO)
- UART receiver and transmitter (full duplex)
- Low voltage reset and low voltage detection
- Watchdog enable (bonding option)
- ICE function for development and down load into flash memory
- Security function to protect code to be read and written.

3.3 Choice of fingerprint sensor

Fingerprint sensors currently used is basically based on three technologies: optical technology, semiconductor silicon technology, ultrasonic technology. Fingerprint Cards AB (Fingerprint Cards) company develop, produce biometric technology. FPC1011F is main product. FPC1011F is a new leading-edge capacitive fingerprint sensor, based on the new Certus Sensor Platform. The reflective capacitive measurement principle gives outstanding fingerprint image quality with 256 gray scale

values in every single pixel. The reflective measurement method sends an electrical signal via the frame directly into the finger. This technique enables the use of an unbeatably hard and thick protective surface coating. FPC1011F is protected against ESD well above 15 kV, as well as scratches, impact and everyday wear-and-tear than 1 million wear cycles [5]. The sensor with its 3D pixel sensing technology can read virtually any finger; dry or wet. The SPI interface enables high-speed readout of data with a minimum of wires. The SPI interface supports a speed of up to the current system clock speed. This feature makes the sensor usable for a wide range of control units.

3.4 SPI communication between microprocessor and the fingerprint sensor

Because FPC1011F interface is SPI, and SPCE061A doesn't have standard SPI port, SPI interface can only be achieved by using a common I/O interface to simulate data transmission for controlling fingerprint sensor in the SPCE061A. Figure 3 is the communication interface circuit between microprocessor and fingerprint sensor.

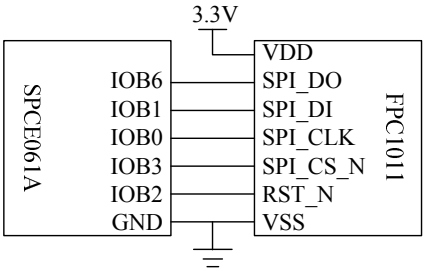

Fig. 3 Communication interface circuit

4. Software design of embedded fingerprint identification system

4.1 Analysis of module and functions

According to the hardware module, software frame mainly includes the fingerprint processing module, LCD module, real-time clock module and the keyboard scan module etc. Fingerprint processing module is responsible for processing command and return code information between microprocessor and fingerprint sensor. According to time sequence, LCD module displays Chinese characters and other symbols. Real-time clock module implements read and write operations of the clock chip. Keyboard scan module based on the 4*4 keyboard design principles identifies whether they have the keystrokes and the keys name.

According to the functions, software mainly includes fingerprint open subprogram, fingerprint management subprogram, password management subprogram, system setup subprogram, real-time clock display subprogram. All subprograms can not be accessed if they do not be permitted by administrator except fingerprint opening subprogram and real-time clock display subprogram. Fingerprint management subprogram includes fingerprint template registration, deletion, clear off and browsing open records. Password management subprogram is composed of changing password and opening. Time setup and date setup make system setup subprogram.

System main program is responsible for initialization, getting the message from the message queue, turning subprogram.

4.2 Simulation of SPI time sequence by SPCE061A

SPI communication system based on SPCE061A is composed of CPU and fingerprint sensor. SPCE061A is main controller which controls fingerprint sensor to implement sensor initialization, data access etc. by the general I/O interface. Following is part code of SPI communication.

```
Start_SPI();
Init_FPC1011F();
SPI_SendByte(READ_SENSOR);
SPI_SendByte(0x00);
for(j=0;j<400;j++)
    {
        SPI_SendByte(READ_SPI_STATUS);
        SPI_SendByte(0x00);
        val = SPI_RecByte();
    }
SPI_SendByte(READ_SPI_DATA);
SPI_SendByte(0x00);
hhDelay(384);
for(i1=0;i1<200;i1++)          //reading pixel matrix of fingerprint sensor array
    {
        hhDelay(170);
        for(j1=0;j1<152;j1++)
        {
            hhDelay(170);
            Img_SPI[cnt++] = SPI_RecByte();
        }
    }
Disable_Spi();
```

5. Conclusion

Compared with other fingerprint identification system which DSP core's computing ability is stronger and controlling ability is poor, the biggest innovation of this system is that the control core of 16-bit SOC chip SPCE061A has not only the stronger control functions of microcontroller, but also a powerful DSP computing power. The system can be applied in fingerprint lock, PDA device, no key car and so on after being extended.

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